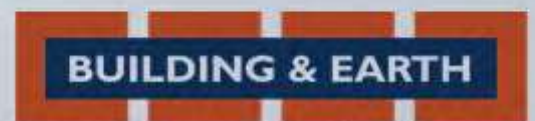




REPORT OF SUBSURFACE EXPLORATION
AND GEOTECHNICAL EVALUATION
CITY OF TULSA (CoT) - MAINTENANCE ZONE 5027
TULSA, OKLAHOMA
BUILDING & EARTH PROJECT NO. TU220175
WALLACE PROJECT NO.: 2240017

PREPARED FOR:
Wallace Design Collective

SEPTEMBER 13, 2022



Geotechnical, Environmental, and Materials Engineers

September 13, 2022



wallace
design
collective

123 North Martin Luther King Jr. Boulevard
Tulsa, Oklahoma 74103

Attention: Mr. Lance Woolsey, P.E., RA

Subject: Report of Subsurface Exploration and Geotechnical Evaluation
City of Tulsa (CoT) – Maintenance Zone 5027
Tulsa, Oklahoma
Building & Earth Project No: TU220175
Wallace Project No.: 2240017

Dear Mr. Woolsey:

Building & Earth Sciences, Inc. has completed the authorized subsurface exploration and geotechnical engineering evaluation for the planned street reconstruction project (Maintenance Zone 5027) for the City of Tulsa.

The purpose of this exploration and evaluation was to determine general subsurface conditions at the site and to identify and address geotechnical matters affecting the proposed street improvements. The recommendations in this report are based on a physical reconnaissance of the site and observation and classification of samples obtained from six (6) test borings conducted within the proposed maintenance zone. Confirmation of the anticipated subsurface conditions during construction is an essential part of geotechnical services.

We appreciate the opportunity to provide consultation services for the proposed project. If you have any questions regarding the information in this report or need any additional information, please call us.

Respectfully Submitted,

BUILDING & EARTH SCIENCES, INC.

Certificate of Authorization, #3975, Expires 6/30/2024

Dharmateja Maganti, E.I.
Project Manager



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APPENDIX

1.0 PROJECT & SITE DESCRIPTION

The subject site is located within a neighborhood approximately 500 feet west of the South Garnett Road and East 21st Street intersection on the north side of East 21st Street in Tulsa, Oklahoma. Based on the information provided to our office, we understand that consideration is being given to reconstruction of the following residential streets per City of Tulsa (CoT) design standards:

- South 109th East Avenue
- East 19th Place
- East 20th Place

Figure 1 below shows the approximate project alignment planned for reconstruction.

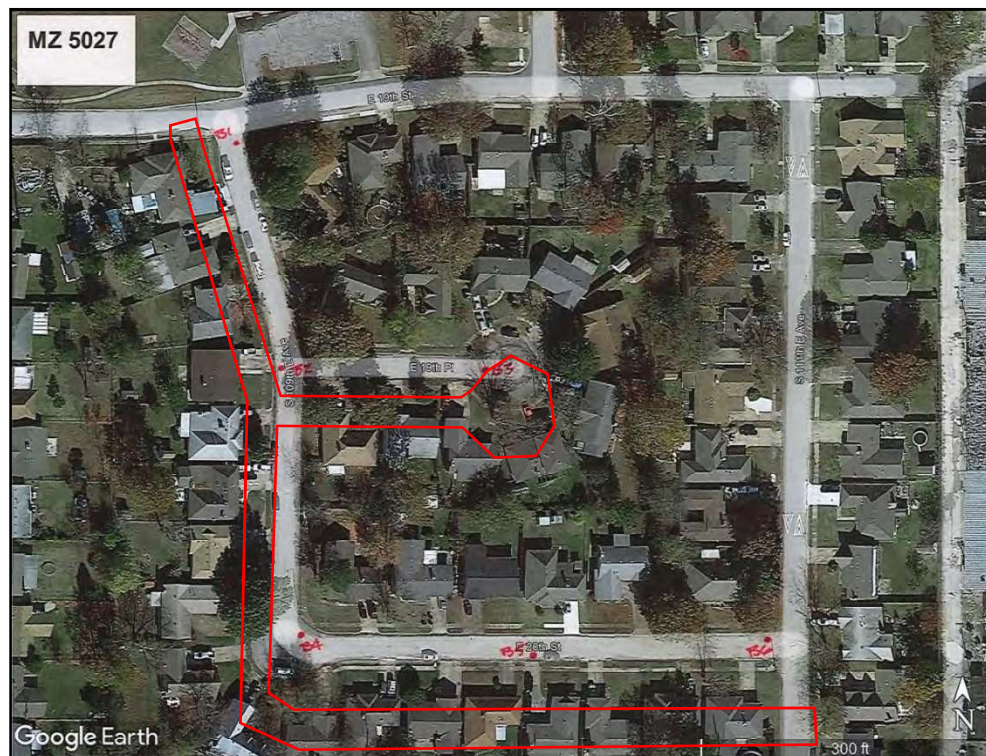


Figure 1: Approximate project alignment planned for reconstruction (Google Earth)

During our subsurface exploration, underground utility markings comprising of gas, water and sewage were noted running parallel to East 20th Street and crossing near HB-04 to the south of the street. A sewage line runs through East 20th Street north of HB-02 and runs along the north side of East 19th Place and crosses west to east through the cul-de-sac. The project site was surrounded by residential homes with a park to the north side of East 19th Street.

The surface of the pavement is comprised of asphaltic concrete. The pavement showed signs of distress including alligator cracking, longitudinal and transverse cracks, block cracking, potholes, and patched areas. Sample pictures showing the general condition of the pavement surface at each boring location are included in the Appendix of this report.

Based on conversations with Mr. Lance Woolsey, we understand that residential streets will be reconstructed using the following City of Tulsa (CoT) Asphalt Pavement and Concrete Pavement Standard Details for Alleys, Residential, and Collector Streets sections (reference: City of Tulsa Standards 726 and 727, dated March 2022).

Per review of the above referenced documents, three (3) flexible pavement sections are developed by CoT for various pavement uses and design structural number, for a pavement life to meet and exceed 25 years. For the different pavement sections, CoT recommends that the subgrade be prepared or stabilized in accordance with Oklahoma Department of Transportation Sections 310 (Method B) and 307, respectively.

Based on the subsurface conditions encountered in the test borings and the unlikelihood of subgrade treatment with a chemical additive due to the project being situated in a residential neighborhood, modified versions of the standard flexible pavement section for high volume interior collector street and rigid pavement section are recommended for this project. Further pavement section recommendations are presented in Section 5 of this report.

2.0 SCOPE OF SERVICES

The authorized subsurface exploration was performed on August 23, 2022, in conformance with our proposal TU24083, dated March 18, 2022. Mr. Darren Burns of Wallace Design Collective authorized our services by signing the referenced proposal on August 11, 2022.

The purpose of the geotechnical exploration was to determine general subsurface conditions at specific boring locations and to gather data on which to base a geotechnical evaluation with respect to the proposed reconstruction. The subsurface exploration for this project consisted of six (6) test borings. The pavement was cored at exploration locations using a Hilti coring machine and 6-inch outside diameter core barrel with diamond impregnated cutting teeth. The cores were transported to our Tulsa, OK laboratory for thickness determination and visual inspection.

Following extraction of the cores, a dynamic cone penetration (DCP) test was performed using a Kessler dual-mass DCP apparatus. The DCP test started at the base of asphalt pavement and continued to depths ranging between about 3 to 4 feet. The results obtained from DCP testing were utilized to estimate the in-place California Bearing Ratio (CBR) of the subgrade soils. Copies of the Kessler DCP reports are included in the Appendix of this report.

The boring locations were determined in the field by a representative of our staff by utilizing Google Earth satellite images, and measuring distances from existing site features, and estimating right angles. As such, the boring locations shown on the Boring Location Plan in the Appendix of this report should be considered approximate.

The soil samples recovered during our site investigation were visually classified and specific samples were selected by the project engineer for laboratory analysis. The laboratory analysis consisted of:

Test	ASTM	No. of Tests
Natural Moisture Content	D2216	25
Atterberg Limits	D4318	6
Material Finer Than No. 200 Sieve by Washing	D1140	2

Table 1: Scope of Laboratory Tests

The results of the laboratory analysis are presented on the enclosed Boring Logs and in tabular form in the Appendix of this report. Descriptions of the laboratory tests that were performed are also included in the Appendix.

The information gathered from the exploration was evaluated to determine if any special subgrade preparation procedures will be required and to develop recommended flexible and rigid pavement sections.

The results of the work are presented within this report that addresses:

- Summary of general pavement surface conditions.
- A description of the subsurface conditions encountered at the boring locations.
- A description of the groundwater conditions observed in the boreholes during drilling. Long-term monitoring is not included in our scope of work.
- Presentation of laboratory test results.

- Site preparation considerations including material types to be expected at the site, treatment of any encountered unsuitable soils, excavation considerations, and surface drainage.
- Compaction requirements and recommended criteria to establish suitable material for structural backfill.
- Recommended flexible and rigid pavement sections for residential streets following City of Tulsa standard specifications.

3.0 GEOTECHNICAL SITE CHARACTERIZATION

The following discussion is intended to create a general understanding of the site from a geotechnical engineering perspective. It is not intended to be a discussion of every potential geotechnical issue that may arise, nor to provide every possible interpretation of the conditions identified. The following conditions and subsequent recommendations assume that significant changes in subsurface conditions do not occur between boreholes. However, anomalous conditions can occur due to variations in existing fill or the geologic conditions at the site, and it will be necessary to evaluate the assumed conditions during pavement subgrade preparation and pavement reconstruction.

3.1 EXISTING SURFACE CONDITIONS

The surface of the streets at the core locations comprised of hot mix asphaltic concrete (HMAC) pavement. Concrete was encountered below the asphalt at boring location HB-01 only. The thicknesses of asphalt and concrete are shown in the table below. Detailed pavement core logs are included in the Appendix of this report.

Boring/Core No.	Asphalt Thickness	Concrete Thickness
HB-01	2.25"	8.75"
HB-02	9.25"	Not encountered
HB-03	10"	Not encountered
HB-04	7.75"	Not encountered
HB-05	8.5"	Not encountered
HB-06	8.5"	Not encountered

Table 2: Summary of Pavement Thickness

3.2 SUBSURFACE CONDITIONS

A generalized stratification summary has been prepared using data from the test borings and is presented in the table below. The stratification depicts the general soil conditions and strata types encountered during our field investigation.

Stratum No.	Typical Thickness	Description	Consistency	Lab Testing Data ⁽²⁾
1	0.4 to 0.7' (Encountered in borings HB-04 and HB-05 only)	Fill Materials: Lean Clays (CL) Dark gray, dark brown, and grayish brown	Medium stiff to stiff	<i>Atterberg Limits:</i> LL = 29, PI = 13 <i>Moisture content:</i> 19 to 23%
2 ⁽¹⁾	Termination Layer	Residuum: Lean Clays (CL), and Fat Clays (CH) with ferrous staining and nodules Various shades and combinations of yellow, brown, red, and gray	Medium stiff to stiff within the upper 2 to 3 feet. Consistency of clay soils generally increase with depth	<i>Atterberg Limits:</i> LL = 35 to 55 PI = 20 to 36 <i>Fines Content:</i> 88 and 89% <i>Moisture content:</i> 18 to 26%

Table 3: Stratification Summary

Notes:

- (1) All borings were terminated in the residuum at depths of about 4 to 4.5 feet below current grades.
- (2) For Atterberg Limits: LL = Liquid Limit, and PI = Plasticity Index.

For specific details on the information obtained from individual borings, please refer to the Boring Logs included in the Appendix.

3.2.1 GROUNDWATER

At the time of drilling, groundwater was not encountered, and the borings were dry upon completion of drilling operations and prior to backfilling. Water levels reported are accurate only for the time and date that the borings were drilled. Long term monitoring of the boreholes was not included as part of our subsurface exploration. The borings were backfilled, and the pavements patched the same day that they were drilled.

4.0 EARTHWORK CONSIDERATIONS

A grading plan was not available at the time of preparing this report. We anticipate that final grades of reconstructed pavements will match existing grades. ***If our assumption is incorrect, Building & Earth should be given the opportunity to review the final grading plans, when they become available, and be contracted to provide supplemental recommendations, if deemed appropriate based on new project information.***

The primary geotechnical considerations for this project are:

- Existing fill materials were encountered in borings HB-04 and HB-05 beneath the pavement and extended to depths of about 1 to 1.5 feet.
- Lower consistency clay soils with elevated moisture contents were encountered to depth of about 2 feet below top of existing pavements.
- The fill materials and residual clays exhibited medium to high plasticity characteristics with a moderate to high potential for shrink and swell.

Recommendations addressing the site conditions are presented in the following sections.

4.1 INITIAL SITE PREPARATION

All pavements should be removed from the proposed reconstruction areas. Approximately 7¾ to 10 inches of asphalt pavement was encountered in borings HB-02 through HB-06. In boring HB-01, 2¼ inches of asphalt pavement was underlain by 8¾ inches of concrete pavement.

Materials disturbed during pavement demolition operations should be undercut to undisturbed materials and backfilled with properly compacted, approved structural fill. A geotechnical engineer should observe demolition operations to evaluate that all unsuitable materials are removed from locations for proposed reconstruction.

Existing underground utility lines are likely present within the planned reconstruction areas. It should be noted that existing utility lines and their trenches can potentially serve as groundwater conduits, which could result in saturation and softening of surrounding soils or subsurface erosion and subsequent vertical migration of the overlying soils. Thorough evaluation of the backfill material condition is recommended to verify that no unsuitable materials are contained within the trench backfill. Any unsuitable material encountered should be removed full-depth and replaced with properly compacted and approved structural fill.

During site preparation activities, the contractor should identify borrow source materials that will be used as structural fill and provide samples to the testing laboratory so that conformance to the Structural Fill requirements outlined below and appropriate moisture-density relationship curves can be determined.

4.2 PAVEMENT SUBGRADE PREPARATION

Based on the subsurface conditions encountered in the borings, a combination of existing fill materials comprised of lean clays, and residual soils comprised of lean clays and fat clays is anticipated to be exposed at cut subgrade level.

Although not encountered in borings HB-04 and HB-05, existing fill could contain unstable and/or soft materials, rock fragments greater than 3 inches in any dimension, debris, organics, and any other deleterious materials.

The near-surface fill materials and residual clay soils encountered in the borings generally exhibited lower consistencies with relatively high moisture contents, which are a concern for unstable subgrade conditions.

Following demolition of the existing pavement and cuts needed to accommodate any grade adjustments for the recommended new pavement sections, the exposed subgrade should be prepared in accordance with the following recommendations.

4.2.1 SUBGRADE PREPARATION METHOD B, ODOT SECTION 310

As a minimum prior to any fill placement, we recommend that the project geotechnical engineer or a qualified representative evaluate the condition of the soils at cut subgrade level. As described above, some unsuitable or unstable areas may be present. Therefore, it is recommended for all pavement areas to be carefully proofrolled with a heavy (20- to 25-ton), loaded tandem axle dump truck, at the following times prior to placement of any new fill or aggregate.

Soft, unstable, or otherwise unsuitable soils identified during the proofrolling process should be undercut and replaced with structural fill. Any unsuitable material is to be removed full-depth and replaced with structural fill as defined in the *Structural Fill* section of this report.

After careful evaluation, the subgrade is to be scarified to depth of 12 inches, moisture conditioned to within range of 1 percent below to 3 percent above the optimum moisture content, and recompacted to at least 95 percent of the material's standard Proctor maximum dry density (ASTM D698 or AASHTO T99).

4.2.2 SUBGRADE EVALUATION PRIOR TO AGGREGATE PLACEMENT

We recommend that the project geotechnical engineer or a qualified representative evaluate the subgrade within 48 hours prior to start of aggregate base course placement by observation of a proofroll with a heavy (20- to 25-ton), loaded tandem axle dump truck. Supplemental proofrolls are recommended following any precipitation, disturbance to finished subgrade, and/or when the subgrade has been exposed for more than 48 hours since the last proofroll.

Depending on climatic and other factors immediately preceding and during construction, instability could exist. Soft, unstable, or otherwise unsuitable soils identified during the proofrolling process should be corrected prior to start of aggregate base placement.

4.3 STRUCTURAL FILL

Although fill placement to achieve design grades is not expected for this project, requirements for structural fill for this project are as follows:

Soil Type	USCS Classification	Property Requirements	Placement Location
Imported Lean Clay, Clayey Sand, or Shale	CL, SC	LL < 40, 7 < PI < 18, $\gamma_d > 100$ pcf, P200 > 15%, Maximum 3" particle size in any dimension	Lower Plasticity Structural Fill to be used in pavement areas as needed
Onsite Fill Materials, Lean Clays, and Fat Clays	CL, CH	N/A	Not suitable for use as lower plasticity structural fill due to medium to high plasticity characteristics.

Table 4: Structural Fill Requirements

Notes:

1. All structural fill should be free of vegetation, topsoil, and any other deleterious materials. The organic content of materials to be used for fill should be less than 3 percent.
2. LL indicates the soil Liquid Limit; PI indicates the soil Plasticity Index; P200 indicates the percent of material by weight that passes the #200 sieve; γ_d indicates the maximum dry density as defined by the density standard outlined in the table below.
3. Laboratory testing of the soils proposed for fill must be performed to verify their conformance with the above recommendations.
4. Any fill to be placed at the site should be reviewed by the geotechnical engineer.
5. The contractor needs to anticipate the need to import lower plasticity structural fill from an approved offsite borrow source for construction.

Placement requirements for structural fill are as follows:

Specification	Requirement
Lift Thickness	Maximum loose lift thickness of 8 to 12 inches, depending on type of compaction equipment used.
Density	At least 95% of the standard Proctor maximum density (ASTM D698 or AASHTO T99)
Moisture	2% below to 2% above the optimum moisture content as determined by ASTM D698 or AASHTO T99
Density Testing Frequency	One test per 150 linear feet per lift with a minimum of three tests performed per lift

Table 5: Structural Fill Placement Requirements

4.4 WET WEATHER CONSTRUCTION

Excessive movement of construction equipment across the site during wet weather may result in ruts, which will collect rainwater, prolonging the time required to dry the subgrade soils.

During rainy periods, additional effort will be required to properly prepare the site and establish/maintain an acceptable subgrade. The difficulty will increase in areas where clay or silty soils are exposed at the subgrade elevation. Grading contractors typically postpone grading operations during wet weather to wait for conditions that are more favorable. Contractors can typically disk or aerate the upper soils to promote drying during intermittent periods of favorable weather. When deadlines restrict postponement of grading operations, additional measures such as undercutting and replacing saturated soils with structural fill or graded crushed aggregate can be utilized to facilitate placement of additional fill material.

5.0 FLEXIBLE PAVEMENT SECTION

The following pavement design criteria were used to aid with determination of the flexible pavement section:

Pavement Design Parameter	Value
Design Life	25 years (given)
Equivalent 18-Kip Single Axle Loads (ESAL)	Minimum 400,000 (given)
Initial Serviceability	4.2 (assumed)
Terminal Serviceability	2.5 (assumed)
Reliability	90% (assumed)
Standard Deviation	0.45 (assumed)
California Bearing Ratio (CBR) of Subgrade	2.0 (estimated for CH)
Structural Numbers:	
HMAC Surface Course (Superpave "S4")	0.42
HMAC Binder Course (Superpave "S3")	0.40
Crushed Stone Base	0.14

Table 6: Flexible Pavement Design Parameter Values

As discussed in the previous section of this report, the subgrade soils are expected to comprise of higher plasticity clay soils that have a moderate to high shrink-swell potential.

All subgrade, base and pavement construction operations should meet minimum requirements of the Oklahoma Department of Transportation (ODOT), Standard Specifications for Highway Construction, dated 2019. The applicable sections of the specifications are identified as follows:

Material	Specification Section
Plant Mix Asphalt Concrete Pavement	411 & 708
Mineral Aggregate Base Materials	303 & 703.01

Table 7: ODOT Specification Sections

Recommended flexible pavement section alternate is presented in the following table. This section has a Structural Number (SN) of 4.32 and ESAL capacity of 430,000, and it is adequate to support an average daily traffic count of twenty-six (26) HS20-44 trucks over a 25-year design life. Alternate pavement sections can be provided upon further request and receipt of actual traffic volume and distribution data for this street maintenance zone.

Minimum Recommended Thickness (in)	Material
2.0	HMAC Surface Course (Superpave "S4")
4.5	HMAC Binder Course (Superpave "S3")
12.0 ⁽¹⁾	Crushed Aggregate Base (ODOT Type "A")
12.0 ⁽²⁾	Subgrade Preparation, Method B ODOT 310

Table 8: Flexible Pavement Section

Note:

1. Placed and compacted in two (2) lifts.
2. Deviation from CoT recommended Asphalt Pavement Standard Details for Alleys, Residential, and Collector Streets sections. The exposed subgrade should be prepared in accordance with Section 4.2 of this report.

In accordance with the ODOT specifications, asphaltic concrete should be compacted within 92 to 97 percent of the theoretical maximum specific gravity of the asphaltic concrete mix. The underlying aggregate base course should be compacted to at least 98 percent of the material's modified Proctor maximum dry density (AASHTO T-180 or ASTM D1557) with a moisture content range of ± 2 percent of the optimum moisture content at the time of placement.

6.0 RIGID PAVEMENT SECTION

The following is the recommended rigid pavement section per CoT design standards.

Minimum Recommended Thickness (in)	Material
6.0	Portland Cement Concrete
6.0 ⁽¹⁾	Type "A" Aggregate Base ODOT 303
12.0 ^{(1) (2)}	Subgrade Preparation, Method B ODOT 310

Table 9: Rigid Pavement Recommendations

Note:

1. Deviation from CoT recommended Concrete Pavement Standard Details for Alleys, Residential, and Collector Streets section.
2. The exposed subgrade should be prepared in accordance with Section 4.2 of this report.

The concrete should be protected against moisture loss, rapid temperature fluctuations, and construction traffic for several days after placement. All pavements should be sloped for positive drainage. We suggest that a curing compound be applied after the concrete has been finished.

Although not referenced in the ODOT specifications, based on our experience with project sites in this region and anticipated traffic loads, we recommend Portland cement concrete should have a minimum 28-day compressive strength of 3,500 psi, maximum slump of 4 inches, and air content of 5 to 7 percent.

In accordance with CoT design standards for concrete pavements, a jointing plan should be developed to control cracking and help preclude surficial migration of water into the base course and subgrade.

All pavements should be sloped, approximately $\frac{1}{4}$ inch per foot, to provide rapid surface drainage. Water allowed to pond on or adjacent to the pavement could saturate the subgrade and cause premature deterioration of the pavements because of loss of strength and stability. Periodic maintenance of the pavement should be anticipated. This should include sealing of cracks and joints and maintaining proper surface drainage to avoid ponding of water on or near the pavement areas.

7.0 SUBGRADE REHABILITATION

The subgrade soils often become disturbed during the period between subgrade preparation and pavement construction. The amount and depth of disturbance will vary with soil type, weather conditions, construction traffic, and drainage.

The engineer should evaluate the subgrade soil during final grading to verify that the subgrade is suitable to receive pavement. The final evaluation may include proofrolling or density tests.

Subgrade rehabilitation can become a point of controversy when different contractors are responsible for subgrade preparation and pavement construction. The construction documents should specifically state which contractor will be responsible for maintaining and rehabilitating the subgrade. Rehabilitation may include moisture conditioning and re-compacting soils. When deadlines or weather restrict grading operations, additional measures such as undercutting and replacing saturated soils with structural fill or graded aggregate base can often be utilized.

8.0 CONSTRUCTION MONITORING

Field verification of site conditions is an essential part of the services provided by the geotechnical consultant. To confirm our recommendations, it will be necessary for Building & Earth personnel to make periodic visits to the site during pavement subgrade preparation. Typical construction monitoring services are listed below.

- Periodic observations and consultations by a member of our engineering staff during pavement subgrade preparation
- Field density tests during base stone, and utility trench backfill placement
- Continuous monitoring and testing during pavement installation
- Molding and testing of concrete cylinders
- Sampling of asphalt for mix verification and coring for determination of in-place thickness and density.

9.0 CLOSING AND LIMITATIONS

This report was prepared for Wallace Design Collective, for specific application to the subject project located in Tulsa, Oklahoma. The information in this report is not transferable. This report should not be used for a different development on the same property without first being evaluated by the engineer.

The recommendations in this report were based on the information obtained from our field exploration and laboratory analysis. The data collected is representative of the locations tested. Variations are likely to occur at other locations throughout the site. Engineering judgment was applied in regards to conditions between borings. It will be necessary to confirm the anticipated subsurface conditions during construction.

This report has been prepared in accordance with generally accepted standards of geotechnical engineering practice. No other warranty is expressed or implied. In the event that changes are made, or anticipated to be made, to the nature, design, or location of the project as outlined in this report, Building & Earth must be informed of the changes and given the opportunity to either verify or modify the conclusions of this report in writing, or the recommendations of this report will no longer be valid.

The scope of services for this project did not include any environmental assessment of the site or identification of pollutants or hazardous materials or conditions. If the owner is concerned about environmental issues Building & Earth would be happy to provide an additional scope of services to address those concerns.

This report is intended for use during design and preparation of specifications and may not address all conditions at the site during construction. Contractors reviewing this information should acknowledge that this document is for design information only.

An article published by the Geoprofessional Business Association (GBA), titled *Important Information About Your Geotechnical Report*, has been included in the Appendix. We encourage all individuals to become familiar with the article to help manage risk.

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GEOTECHNICAL INVESTIGATION METHODOLOGIES

The subsurface exploration, which is the basis of the recommendations of this report, has been performed in accordance with industry standards. Detailed methodologies employed in the investigation are presented in the following sections.

PAVEMENT CORES

Pavement cores were collected at random locations using a 6-inch outside diameter core barrel with a diamond-impregnated bit. The pavement cores were reviewed to determine the existing pavement section and its thickness

HAND AUGER BORINGS

Hand auger borings were drilled with a 3-inch diameter auger to advance the hole below the existing grade. A Building & Earth representative collected samples of the subsurface soils at regular depth intervals and at depths where a change in lithology occurred.

DUAL MASS DYNAMIC CONE PENETRATION TESTING (KESSLER DCP)

Dynamic Cone Penetration (DCP) tests were performed to estimate the in-place soil consistency and in-place California Bearing Ratio (CBR) of the subsurface soils by in-situ methods.

The DCP tests were performed starting at the top of existing subgrade to the desired depth of investigation. The DCP test was performed using the Kessler DCP with Dual Mass Hammer. A cone tip with base diameter of 0.79 inches and tip angle of 60 degrees was driven into the subsurface soils by a 17.6 pound (dual mass) sliding hammer from a height of 22.6 inches. The depth of cone penetration was measured at selected hammer drop intervals and the soil shear strength was reported in terms of DCP index. The DCP index is based on the average penetration depth resulting from one blow of the 17.6-pound hammer. The Kessler DCP can be used to estimate the strength characteristics of clay soils. The in-place CBR values of the subsurface soils at the test locations were estimated using empirical correlations between DCP index and California Bearing Ratio (CBR). The DCP test results are included in a subsequent section of the Appendix.

BORING LOG DESCRIPTION

Building & Earth Sciences, Inc. used the gINT software program to prepare the attached boring logs. The gINT program provides the flexibility to custom design the boring logs to include the pertinent information from the subsurface exploration and results of our laboratory analysis. The soil and laboratory information included on our logs is summarized below:

DEPTH AND ELEVATION

The depth below the ground surface and the corresponding elevation are shown in the first two columns.

SAMPLE TYPE

The method used to collect the sample is shown. The typical sampling methods include Split Spoon Sampling, Shelby Tube Sampling, Grab Samples, and Rock Core. A key is provided at the bottom of the log showing the graphic symbol for each sample type.

SAMPLE NUMBER

Each sample collected is numbered sequentially.

BLOWS PER INCREMENT, REC%, RQD%

When Standard Split Spoon sampling is used, the blows required to drive the sampler each 6-inch increment are recorded and shown in column 5. When rock core is obtained the recovery ratio (REC%) and Rock Quality Designation (RQD%) is recorded.

SOIL DATA

Column 6 is a graphic representation of four different soil parameters. Each of the parameters use the same graph, however, the values of the graph subdivisions vary with each parameter. Each parameter presented on column 6 is summarized below:

- **N-value**- The Standard Penetration Test N-value, obtained by adding the number of blows required to drive the sampler the final 12 inches, is recorded . The graph labels range from 0 to 50.
- **Qu** – Unconfined Compressive Strength estimate from the Pocket Penetrometer test in tons per square foot (tsf). The graph labels range from 0 to 5 tsf.
- **Atterberg Limits** – The Atterberg Limits are plotted with the plastic limit to the left, and liquid limit to the right, connected by a horizontal line. The difference in the plastic and liquid limits is referred to as the Plasticity Index. The Atterberg Limits test results are also included in the Remarks column on the far right of the boring log. The Atterberg Limits graph labels range from 0 to 100%.
- **Moisture** – The Natural Moisture Content of the soil sample as determined in our laboratory.

SOIL DESCRIPTION

The soil description prepared in accordance with ASTM D2488, Visual Description of Soil Samples. The Munsel Color chart is used to determine the soil color. Strata changes are indicated by a solid line, with the depth of the change indicated on the left side of the line and the elevation of the change indicated on the right side of the line. If subtle changes within a soil type occur, a broken line is used. The Boring Termination or Auger Refusal depth is shown as a solid line at the bottom of the boring.

GRAPHIC

The graphic representation of the soil type is shown. The graphic used for each soil type is related to the Unified Soil Classification chart. A chart showing the graphic associated with each soil classification is included.

REMARKS

Remarks regarding borehole observations, and additional information regarding the laboratory results and groundwater observations.

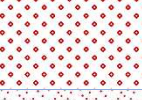
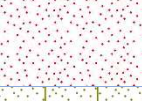
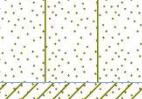
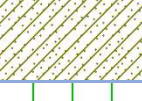
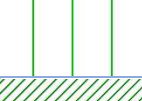
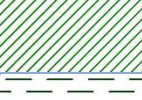
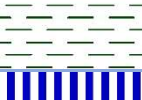
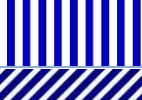
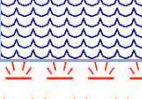
Major Divisions			Symbols		Group Name & Typical Description
			Lithology	Group	
Coarse Grained Soils More than 50% of material is larger than No. 200 sieve size	Gravel and Gravelly Soils More than 50% of coarse fraction is larger than No. 4 sieve	Clean Gravels (Less than 5% fines)		GW	Well-graded gravels, gravel – sand mixtures, little or no fines
				GP	Poorly-graded gravels, gravel – sand mixtures, little or no fines
		Gravels with Fines (More than 12% fines)		GM	Silty gravels, gravel – sand – silt mixtures
				GC	Clayey gravels, gravel – sand – clay mixtures
	Sand and Sandy Soils More than 50% of coarse fraction is smaller than No. 4 sieve	Clean Sands (Less than 5% fines)		SW	Well-graded sands, gravelly sands, little or no fines
				SP	Poorly-graded sands, gravelly sands, little or no fines
		Sands with Fines (More than 12% fines)		SM	Silty sands, sand – silt mixtures
				SC	Clayey sands, sand – clay mixtures
Fine Grained Soils More than 50% of material is smaller than No. 200 sieve size	Silts and Clays Liquid Limit less than 50	Inorganic		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silt with slight plasticity
				CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		Organic		OL	Organic silts and organic silty clays of low plasticity
	Silts and Clays Liquid Limit greater than 50	Inorganic		MH	Inorganic silts, micaceous or diatomaceous fine sand, or silty soils
				CH	Inorganic clays of high plasticity
		Organic		OH	Organic clays of medium to high plasticity, organic silts
Highly Organic Soils				PT	Peat, humus, swamp soils with high organic contents

Table 1: Soil Classification Chart (based on ASTM D2487)

Building & Earth Sciences classifies soil in general accordance with the Unified Soil Classification System (USCS) presented in ASTM D2487. Table 1 and Figure 1 exemplify the general guidance of the USCS. Soil consistencies and relative densities are presented in general accordance with Terzaghi, Peck, & Mesri's (1996) method, as shown on Table 2, when quantitative field and/or laboratory data is available. Table 2 includes Consistency and Relative Density correlations with N-values obtained using either a manual hammer (60 percent efficiency) or automatic hammer (90 percent efficiency). The *Blows Per Increment* and *SPT N-values* displayed on the boring logs are the unaltered values measured in the field. When field and/or laboratory data is not available, we may classify soil in general accordance with the Visual Manual Procedure presented in ASTM D2488.

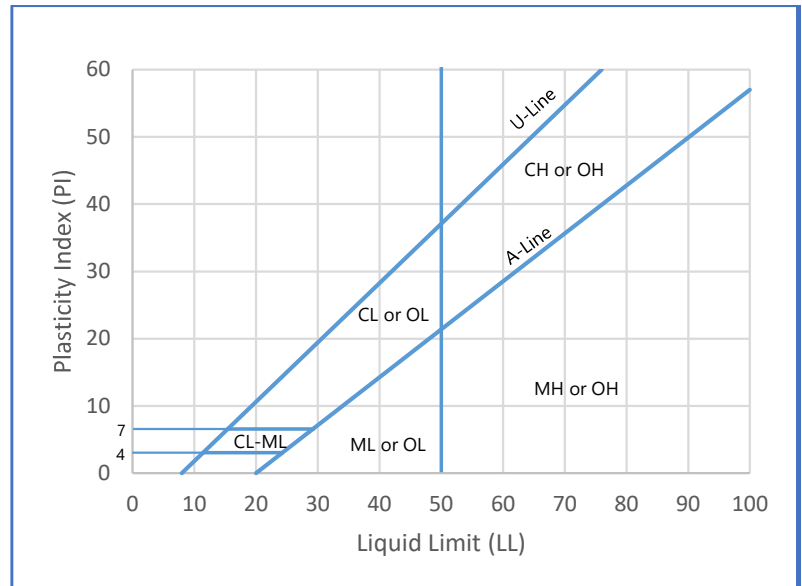


Figure 1: Plasticity Chart (based on ASTM D2487)

Non-cohesive: Coarse-Grained Soil			Cohesive: Fine-Grained Soil			
SPT Penetration (blows/foot)		Relative Density	SPT Penetration (blows/foot)		Consistency	Estimated Range of Unconfined Compressive Strength (tsf)
			Automatic Hammer*	Manual Hammer		
Automatic Hammer*	Manual Hammer		< 2	< 2	Very Soft	< 0.25
0 - 3	0 - 4	Very Loose	2 - 3	2 - 4	Soft	0.25 – 0.50
3 - 8	4 - 10	Loose	3 - 6	4 - 8	Medium Stiff	0.50 – 1.00
8 - 23	10 - 30	Medium Dense	6 - 12	8 - 15	Stiff	1.00 – 2.00
23 - 38	30 - 50	Dense	12 - 23	15 - 30	Very Stiff	2.00 – 4.00
> 38	> 50	Very Dense	> 23	> 30	Hard	> 4.00

Table 2: Soil Consistency and Relative Density (based on Terzaghi, Peck & Mesri, 1996)

* - Modified based on 80% hammer efficiency

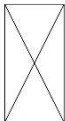
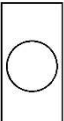
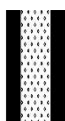
	Standard Penetration Test ASTM D1586 or AASHTO T-206		Dynamic Cone Penetrometer (Sower DCP) ASTM STP-399
	Shelby Tube Sampler ASTM D1587		No Sample Recovery
	Rock Core Sample ASTM D2113		Groundwater at Time of Drilling
	Auger Cuttings		Groundwater as Indicated

Table 1: Symbol Legend

Soil	Particle Size	U.S. Standard
Boulders	Larger than 300 mm	N.A.
Cobbles	300 mm to 75 mm	N.A.
Gravel	75 mm to 4.75 mm	3-inch to #4 sieve
Coarse	75 mm to 19 mm	3-inch to ¾-inch sieve
Fine	19 mm to 4.75 mm	¾-inch to #4 sieve
Sand	4.75 mm to 0.075 mm	#4 to #200 Sieve
Coarse	4.75 mm to 2 mm	#4 to #10 Sieve
Medium	2 mm to 0.425 mm	#10 to #40 Sieve
Fine	0.425 mm to 0.075 mm	#40 to #200 Sieve
Fines	Less than 0.075 mm	Passing #200 Sieve
Silt	Less than 5 µm	N.A.
Clay	Less than 2 µm	N.A.

Table 2: Standard Sieve Sizes

N-Value 	Standard Penetration Test Resistance calculated using ASTM D1586 or AASHTO T-206. Calculated as sum of original, field recorded values.	Atterberg Limits 	A measure of a soil's plasticity characteristics in general accordance with ASTM D4318. The soil Plasticity Index (PI) is representative of this characteristic and is bracketed by the Liquid Limit (LL) and the Plastic Limit (PL).
Qu 	Unconfined compressive strength, typically estimated from a pocket penetrometer. Results are presented in tons per square foot (tsf).	% Moisture 	Percent natural moisture content in general accordance with ASTM D2216.

Table 3: Soil Data

Hollow Stem Auger	Flights on the outside of the shaft advance soil cuttings to the surface. The hollow stem allows sampling through the middle of the auger flights.
Mud Rotary / Wash Bore	A cutting head advances the boring and discharges a drilling fluid to support the borehole and circulate cuttings to the surface.
Solid Flight Auger	Flights on the outside bring soil cuttings to the surface. Solid stem requires removal from borehole during sampling.
Hand Auger	Cylindrical bucket (typically 3-inch diameter and 8 inches long) attached to a metal rod and turned by human force.

Table 4: Soil Drilling Methods

Descriptor	Meaning
Trace	Likely less than 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

Table 5: Descriptors

Manual Hammer	The operator tightens and loosens the rope around a rotating drum assembly to lift and drop a sliding, 140-pound hammer falling 30 inches.
Automatic Trip Hammer	An automatic mechanism is used to lift and drop a sliding, 140-pound hammer falling 30 inches.
Dynamic Cone Penetrometer (Sower DCP) ASTM STP-399	Uses a 15-pound steel mass falling 20 inches to strike an anvil and cause penetration of a 1.5-inch diameter cone seated in the bottom of a hand augered borehole. The blows required to drive the embedded cone a depth of 1-3/4 inches have been correlated by others to N-values derived from the Standard Penetration Test (SPT).

Table 6: Sampling Methods

Non-plastic	A 1/8-inch thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Table 7: Plasticity

Dry	Absence of moisture, dusty, dry to the touch.
Moist	Damp but no visible water.
Wet	Visible free water, usually soil is below water table.

Table 8: Moisture Condition

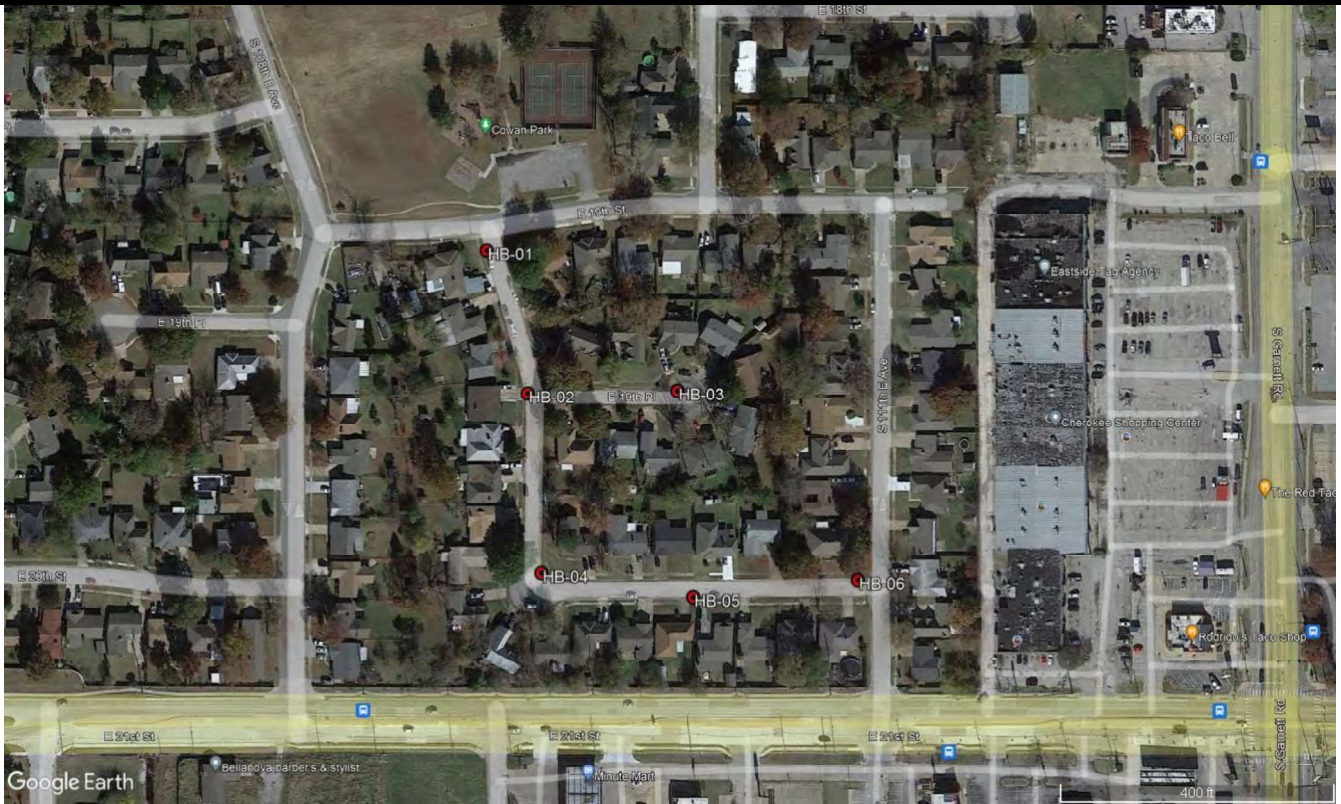
Stratified	Alternating layers of varying material or color with layers at least 1/2 inch thick.
Laminated	Alternating layers of varying material or color with layers less than 1/4 inch thick.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensides	Fracture planes appear polished or glossy, sometimes striated.
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown.
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay.
Homogeneous	Same color and appearance throughout.

Table 9: Structure

<i>Hatch</i>	<i>Description</i>	<i>Hatch</i>	<i>Description</i>	<i>Hatch</i>	<i>Description</i>
	GW - Well-graded gravels, gravel – sand mixtures, little or no fines		Asphalt		Clay with Gravel
	GP - Poorly-graded gravels, gravel – sand mixtures, little or no fines		Aggregate Base		Sand with Gravel
	GM - Silty gravels, gravel – sand – silt mixtures		Topsoil		Silt with Gravel
	GC - Clayey gravels, gravel – sand – clay mixtures		Concrete		Gravel with Sand
	SW - Well-graded sands, gravelly sands, little or no fines		Coal		Gravel with Clay
	SP - Poorly-graded sands, gravelly sands, little or no fines		CL-ML - Silty Clay		Gravel with Silt
	SM - Silty sands, sand – silt mixtures		Sandy Clay		Limestone
	SC - Clayey sands, sand – clay mixtures		Clayey Chert		Chalk
	ML - Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silt with slight plasticity		Low and High Plasticity Clay		Siltstone
	CL - Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		Low Plasticity Silt and Clay		Till
	OL - Organic silts and organic silty clays of low plasticity		High Plasticity Silt and Clay		Sandy Clay with Cobbles and Boulders
	MH - Inorganic silts, micaceous or diatomaceous fine sand, or silty soils		Fill		Sandstone with Shale
	CH - Inorganic clays of high plasticity		Weathered Rock		Coral
	OH - Organic clays of medium to high plasticity, organic silts		Sandstone		Boulders and Cobbles
	PT - Peat, humus, swamp soils with high organic contents		Shale		Soil and Weathered Rock

Table 1: Key to Hatches Used for Boring Logs and Soil Profiles

BORING LOCATION PLAN



**REFERENCE USED
TO PRODUCE THIS
DRAWING:**

Google Earth Satellite
Imagery dated June 2022

BORING LOCATION PLAN

DATE: 08/11/2022

PROJECT NO.

TU220175

PROJECT NAME / LOCATION:

CoT Maintenance Zone 5027
Tulsa, Oklahoma

SCALE:

As Shown

BUILDING & EARTH

Geotechnical, Environmental, and Materials Engineers

PAVEMENT CORE PICTURES

HB-01

TOP



Logged By: Quinton Mann

Date: 8/11/2022

CORE LOG

CORE LAYER DATA (FROM TOP TO BOTTOM)

		Sample No	Layer Type	Layer Thickness (in)	Layer Characteristics*
Project No:	TU220175	1	Asphalt Concrete	2.25	Type C
Location:	Tulsa	2	Portland Cement Concrete	8.75	
County:	Tulsa				
Core No:	HB-01				
Station:	NA				
Lane Direction:	NA				
GPS:	36.135400 - 95.855060				
			Total Core Thickness	11	*Asphalt type based on visual observation only

CORE DATA

Surface Material Type: ☒ A.C. ☒ P.C.C. ☐ Continuously Reinforced ConcreteStripping or Separation in Asphalt: ☐ Stripping ☐ Separation ☐ N/AHoneycomb or "D" cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☒ N/A

HB-02

TOP



Logged By: Quinton Mann

Date: 8/11/2022

CORE LOG

CORE LAYER DATA (FROM TOP TO BOTTOM)

		Sample No	Layer Type	Layer Thickness (in)	Layer Characteristics*
Project No:	TU220175	1	Asphalt Concrete	3.5	Type C
Location:	Tulsa	2	Asphalt Concrete	5.75	Type A
County:	Tulsa				
Core No:	HB-02				
Station:	NA				
Lane Direction:	NA				
GPS:	36.134819 - 95.854851				
			Total Core Thickness	9.25	*Asphalt type based on visual observation only

CORE DATA

Surface Material Type: ☒ A.C. ☐ P.C.C. ☐ Continuously Reinforced ConcreteStripping or Separation in Asphalt: ☐ Stripping ☐ Separation ☒ N/AHoneycomb or "D" cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☒ N/A

HB-03

TOP



Logged By: Quinton Mann

Date: 8/11/2022

CORE LOG

CORE LAYER DATA (FROM TOP TO BOTTOM)

		Sample No	Layer Type	Layer Thickness (in)	Layer Characteristics*
Project No:	TU220175	1	Asphalt Concrete	5.25	Type C
Location:	Tulsa	2	Asphalt Concrete	4.75	Type A
County:	Tulsa				
Core No:	HB-03				
Station:	NA				
Lane Direction:	NA				
GPS:	36.134830 - 95.854100				
			Total Core Thickness	10	*Asphalt type based on visual observation only

CORE DATA

Surface Material Type: ☒ A.C. ☐ P.C.C. ☐ Continuously Reinforced ConcreteStripping or Separation in Asphalt: ☐ Stripping ☒ Separation ☐ N/AHoneycomb or "D" cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☒ N/A

HB-04

TOP



Logged By: Quinton Mann

Date: 8/11/2022

CORE LOG

CORE LAYER DATA (FROM TOP TO BOTTOM)

		Sample No	Layer Type	Layer Thickness (in)	Layer Characteristics*
Project No:	TU220175	1	Asphalt Concrete	2.75	Type C
Location:	Tulsa	2	Asphalt Concrete	5	Type A
County:	Tulsa				
Core No:	HB-04				
Station:	NA				
Lane Direction:	NA				
GPS:	36.134092				
	-95.854780				
			Total Core Thickness	7.75	*Asphalt type based on visual observation only

CORE DATA

Surface Material Type: ☒ A.C. ☐ P.C.C. ☐ Continuously Reinforced ConcreteStripping or Separation in Asphalt: ☐ Stripping ☐ Separation ☒ N/AHoneycomb or "D" cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☒ N/A

HB-05

TOP



Logged By: Quinton Mann

Date: 8/11/2022

CORE LOG

CORE LAYER DATA (FROM TOP TO BOTTOM)

		Sample No	Layer Type	Layer Thickness (in)	Layer Characteristics*
Project No:	TU220160	1	Asphalt Concrete	3.5	Type C
Location:	Tulsa	2	Asphalt Concrete	5	Type A
County:	Tulsa				
Core No:	HB-05				
Station:	NA				
Lane Direction:	NA				
GPS:	36.133996				
	-95.854021				
			Total Core Thickness	8.5	*Asphalt type based on visual observation only

CORE DATA

Surface Material Type: ☒ A.C. ☐ P.C.C. ☐ Continuously Reinforced ConcreteStripping or Separation in Asphalt: ☐ Stripping ☒ Separation ☒ N/AHoneycomb or "D" cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☒ N/A

HB-06

TOP



Logged By: Quinton Mann

Date: 8/11/2022

CORE LOG

CORE LAYER DATA (FROM TOP TO BOTTOM)

		Sample No	Layer Type	Layer Thickness (in)	Layer Characteristics*
Project No:	TU220175	1	Asphalt Concrete	3.25	Type C
Location:	Tulsa	2	Asphalt Concrete	5.25	Type A
County:	Tulsa				
Core No:	HB-06				
Station:	NA				
Lane Direction:	NA				
GPS:	36.134063 - 95.853196				
			Total Core Thickness	8.5	*Asphalt type based on visual observation only

CORE DATA

Surface Material Type: ☒ A.C. ☐ P.C.C. ☐ Continuously Reinforced ConcreteStripping or Separation in Asphalt: ☐ Stripping ☐ Separation ☒ N/AHoneycomb or "D" cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☒ N/A

BORING LOGS



Designation: HB-01

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

LOCATION: Tulsa, OK
DATE DRILLED: 8/23/22
WEATHER: Overcast
ELEVATION:
DRILL CREW: Building & Earth
LOGGED BY: Q. Mann

SAMPLE TYPE Grab Sample

Qu POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH

Birmingham, AL • Auburn, AL • Huntsville, AL • Montgomery, AL
Tuscaloosa, AL • Columbus, GA • Louisville, KY • Raleigh, NC • Dunn, NC
Jacksonville, NC • Springdale, AR • Little Rock, AR • Ft. Smith, AR • Tulsa, OK
Oklahoma City, OK • DFW Metroplex, TX • Virginia Beach, VA



Designation: HB-02

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

LOCATION: Tulsa, OK
DATE DRILLED: 8/23/22
WEATHER: Sunny
ELEVATION:
DRILL CREW: Building & Earth
LOGGED BY: O. Mann

SAMPLE TYPE Grab Sample

Qu POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH

Birmingham, AL • Auburn, AL • Huntsville, AL • Montgomery, AL
Tuscaloosa, AL • Columbus, GA • Louisville, KY • Raleigh, NC • Dunn, NC
Jacksonville, NC • Springdale, AR • Little Rock, AR • Ft. Smith, AR • Tulsa, OK
Oklahoma City, OK • DFW Metroplex, TX • Virginia Beach, VA



Designation: HB-03

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

LOCATION: Tulsa, OK
DATE DRILLED: 8/23/22
WEATHER: Sunny
ELEVATION:
DRILL CREW: Building & Earth
LOGGED BY: Q. Mann

SAMPLE TYPE Grab Sample

Qu POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH

Birmingham, AL • Auburn, AL • Huntsville, AL • Montgomery, AL
Tuscaloosa, AL • Columbus, GA • Louisville, KY • Raleigh, NC • Dunn, NC
Jacksonville, NC • Springdale, AR • Little Rock, AR • Ft. Smith, AR • Tulsa, OK
Oklahoma City, OK • DFW Metroplex, TX • Virginia Beach, VA



Designation: HB-04

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

LOCATION: Tulsa, OK
DATE DRILLED: 8/23/22
WEATHER: Sunny
ELEVATION:
DRILL CREW: Building & Earth
LOGGED BY: Q. Mann

SAMPLE TYPE Grab Sample

Qu POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH

Birmingham, AL • Auburn, AL • Huntsville, AL • Montgomery, AL
Tuscaloosa, AL • Columbus, GA • Louisville, KY • Raleigh, NC • Dunn, NC
Jacksonville, NC • Springdale, AR • Little Rock, AR • Ft. Smith, AR • Tulsa, OK
Oklahoma City, OK • DFW Metroplex, TX • Virginia Beach, VA



Designation: HB-05

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

LOCATION: Tulsa, OK
DATE DRILLED: 8/23/22
WEATHER: Sunny
ELEVATION:
DRILL CREW: Building & Earth
LOGGED BY: O. Mann

SAMPLE TYPE Grab Sample

Qu POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH

Birmingham, AL • Auburn, AL • Huntsville, AL • Montgomery, AL
Tuscaloosa, AL • Columbus, GA • Louisville, KY • Raleigh, NC • Dunn, NC
Jacksonville, NC • Springdale, AR • Little Rock, AR • Ft. Smith, AR • Tulsa, OK
Oklahoma City, OK • DFW Metroplex, TX • Virginia Beach, VA

PROJECT NAME: City of Tulsa - Maintenance Zone 5027
PROJECT NUMBER: TU220175
DRILLING METHOD: Hand Auger
EQUIPMENT USED: Hand Auger/Kessler DCP
HAMMER TYPE: Manual
BORING LOCATION: 36.134063; -95.853196

LOCATION: Tulsa, OK
DATE DRILLED: 8/23/22
WEATHER: Sunny
ELEVATION:
DRILL CREW: Building & Earth
LOGGED BY: Q. Mann

DEPTH (ft)	ELEVATION (ft)	SAMPLE TYPE	SAMPLE NO.	BLOWS PER INCREMENT	☐ N-Value ☐ 10 20 30 40 ☐ Qu (tsf) ☐ 1 2 3 4 Atterberg Limits 20 40 60 80 % Moisture 20 40 60 80	LAB DATA	SOIL DESCRIPTION	GRAPHIC	REMARKS
							ASPHALT: 8.5"		
		Hand	1		☒ ☒	Sample 1 LL: 35 PL: 15 PI: 20 M: 23.4%	0.8 2.0		
		Hand	2		☒	Sample 2 M: 19.2%	2.0		
		Hand	3		☒	Sample 3 M: 24.7%			
		Hand	4		☒	Sample 4 M: 22.0%	4.0		
5							Boring Terminated at 4 feet.		

SAMPLE TYPE  Grab Sample

N-VALUE STANDARD PENETRATION RESISTANCE (AASHTO T-206)

% MOISTURE PERCENT NATURAL MOISTURE CONTENT

 GROUNDWATER LEVEL IN THE BOREHOLE AT TIME OF DRILLING

 STABILIZED GROUNDWATER LEVEL

REC RECOVERY

RQD ROCK QUALITY DESIGNATION **PL:** PLASTIC LIMIT **F:** PERCENT PASSING NO. 200 SIEVE

UD UNDISTURBED

Qu POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH

LL: LIQUID LIMIT **M:** NATURAL MOISTURE CONTENT

PI: PLASTICITY INDEX

Groundwater not encountered at time of drilling. Borehole backfilled on date drilled unless otherwise noted. Consistency based on Kessler DCP data.

KESSLER DCP RESULTS

DCP TEST DATA

Project: TU220175 COT Maintenance Zone 5027

Date: 23-Aug-22

Location: HB-01

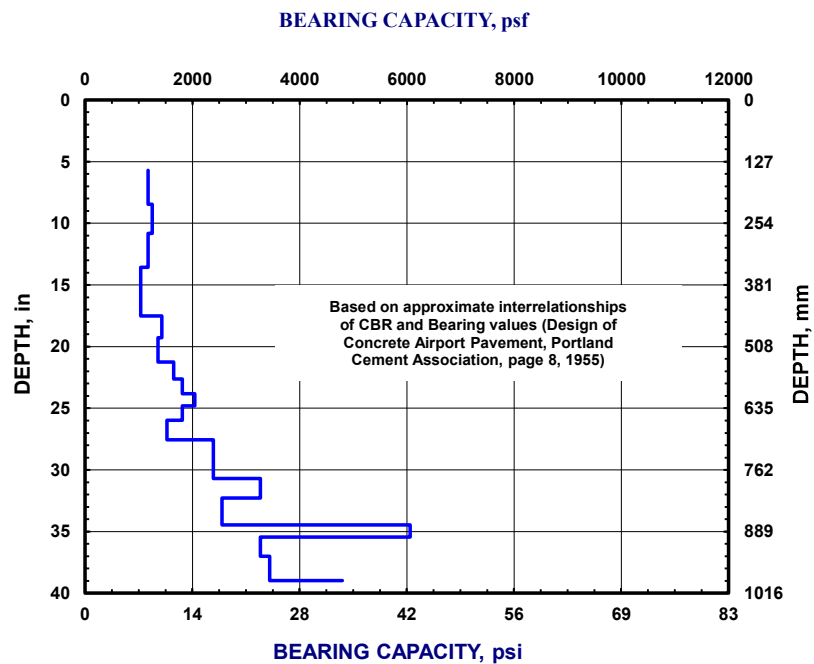
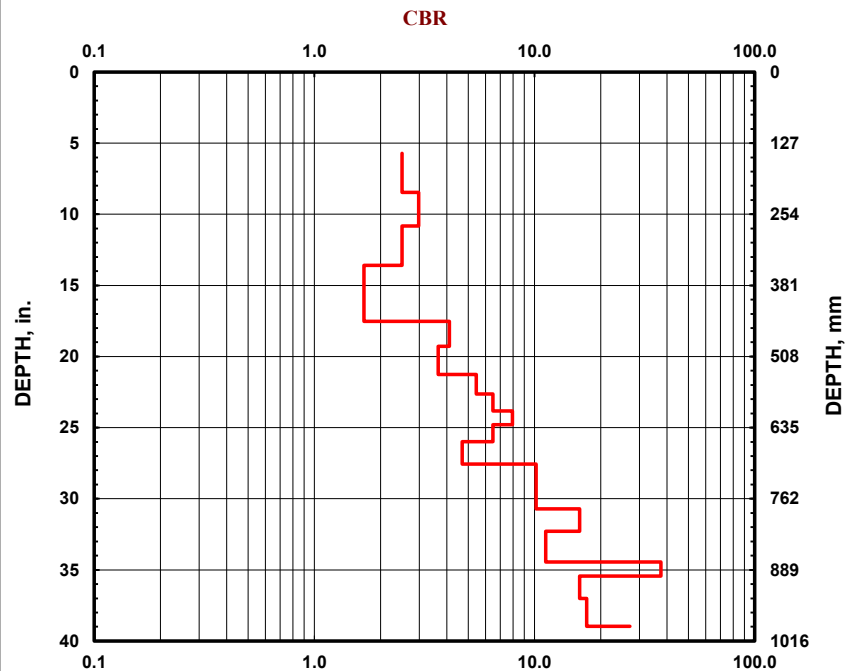
Soil Type(s):

Hammer

- ☐ 10.1 lbs.
- ☒ 17.6 lbs.
- ☐ Both hammers used

Soil Type

- ☐ CH
- ☒ CL
- ☐ All other soils

[illegible]

DCP TEST DATA

Project: TU220175 COT Maintenance Zone 5027

Date: 23-Aug-22

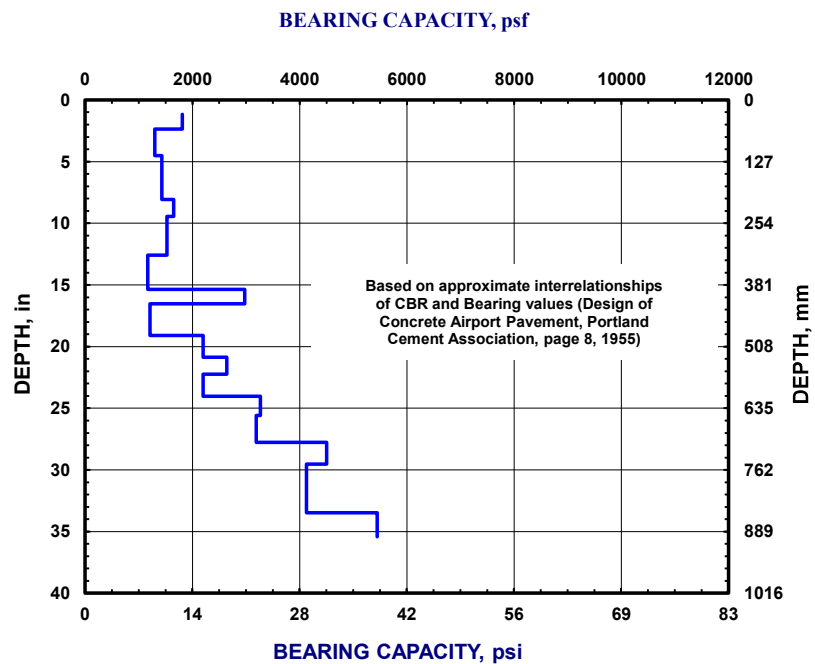
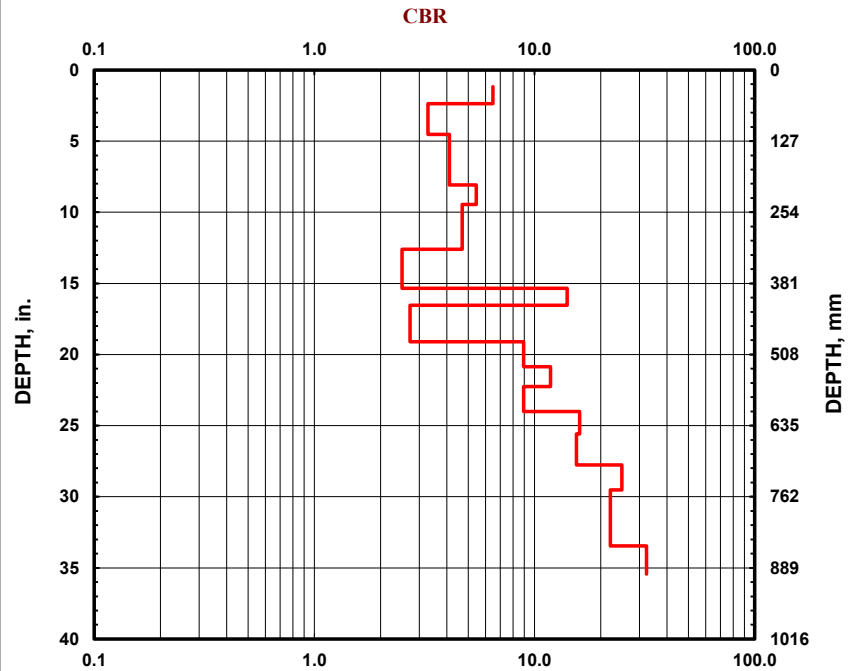
Location: HB-02

Soil Type(s): _____

Hammer
☐ 10.1 lbs.
☒ 17.6 lbs.
☐ Both hammers used

Soil Type
☒ CH
☐ CL
☐ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
1	30	1
1	60	1
1	115	1
1	160	1
1	205	1
1	240	1
1	280	1
1	320	1
2	390	1
1	420	1
2	485	1
2	530	1
2	565	1
3	610	1
4	650	1
5	705	1
5	750	1
5	800	1
7	850	1
7	900	1



DCP TEST DATA

Project: TU220175 COT Maintenance Zone 5027

Date: 23-Aug-22

Location: HB-03

Soil Type(s):

☐ 10,1 lbs.

☐ 10,1 lbs.

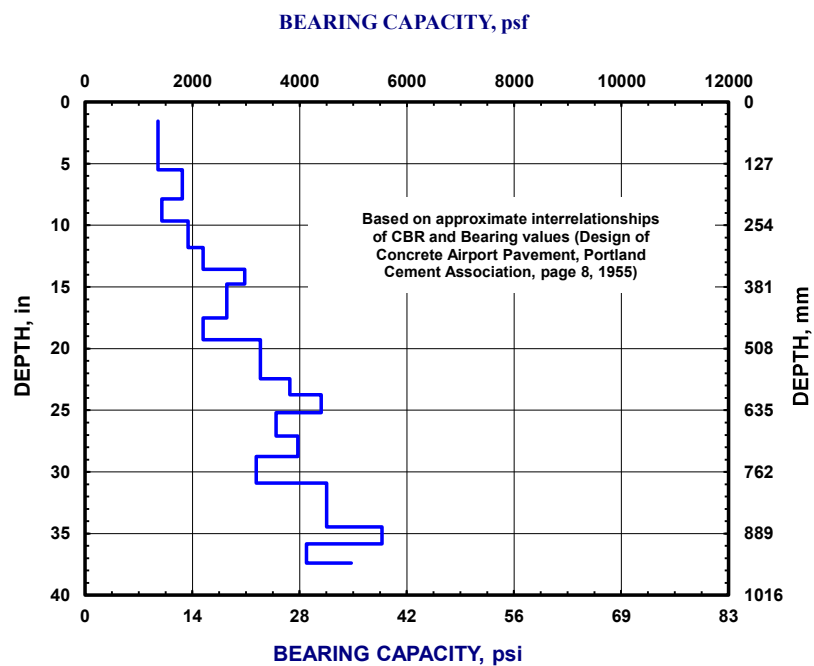
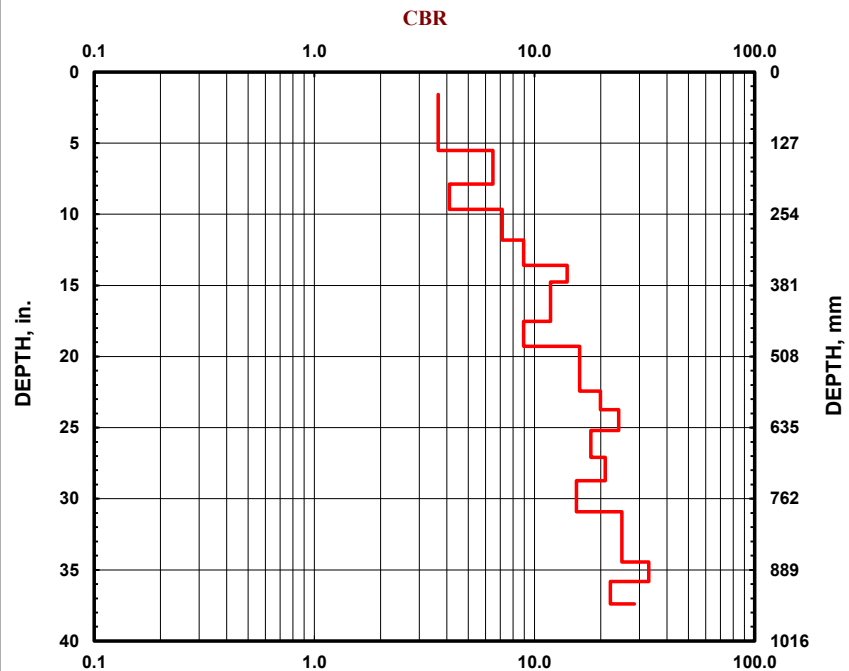
● 17.6 lbs.

☐ Both hammers used

○ CH

- CL

☐ All other soils

[illegible]

DCP TEST DATA

Project: TU220175 COT Maintenance Zone 5027

Date: 23-Aug-22

Location: HB-04

Soil Type(s): Type in the soil type

Hammer

☐ 10.1 lbs.

☒ 17.6 lbs.

☐ Both hammers used

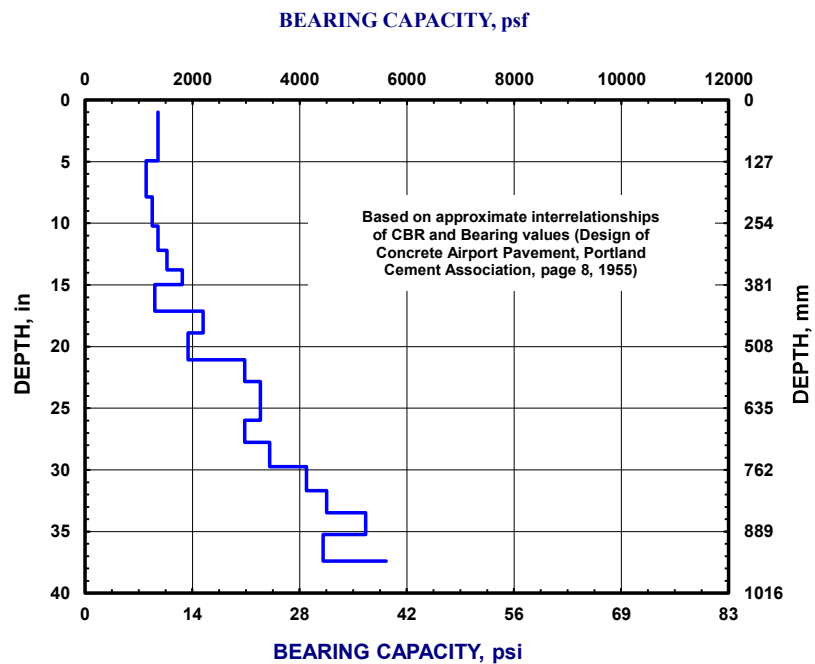
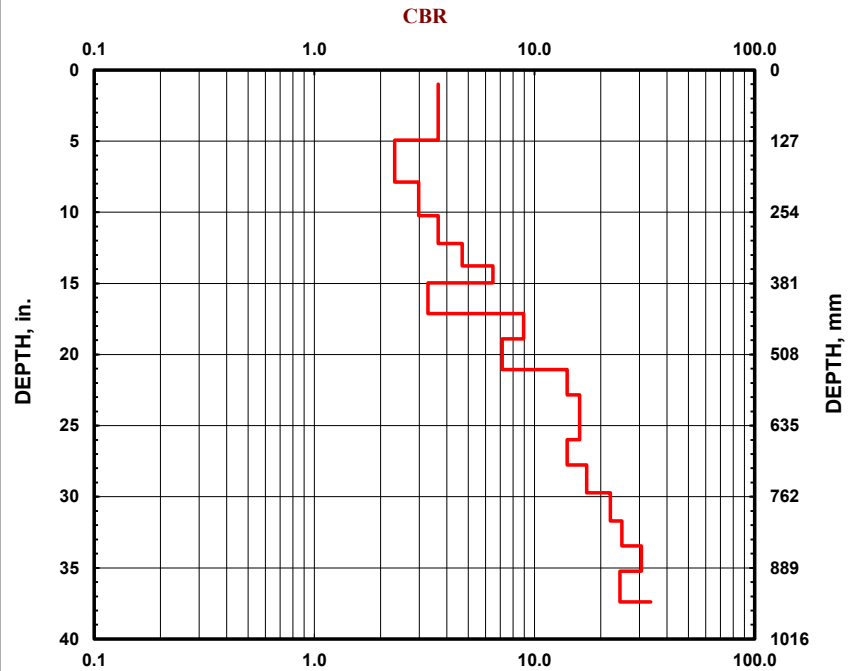
Soil Type

☒ CH

☐ CL

☐ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
1	25	1
1	75	1
1	125	1
1	200	1
1	260	1
1	310	1
1	350	1
1	380	1
2	435	1
2	480	1
3	535	1
3	580	1
3	620	1
3	660	1
4	705	1
5	755	1
5	805	1
6	850	1
6	895	1
8	950	1



DCP TEST DATA

Project: TU220175 COT Maintenance Zone 5027

Date: 23-Aug-22

Location: HB-05

Soil Type(s):

☐ 10,1 lbs.

☐ 10,1 lbs.

● 17.6 lbs.

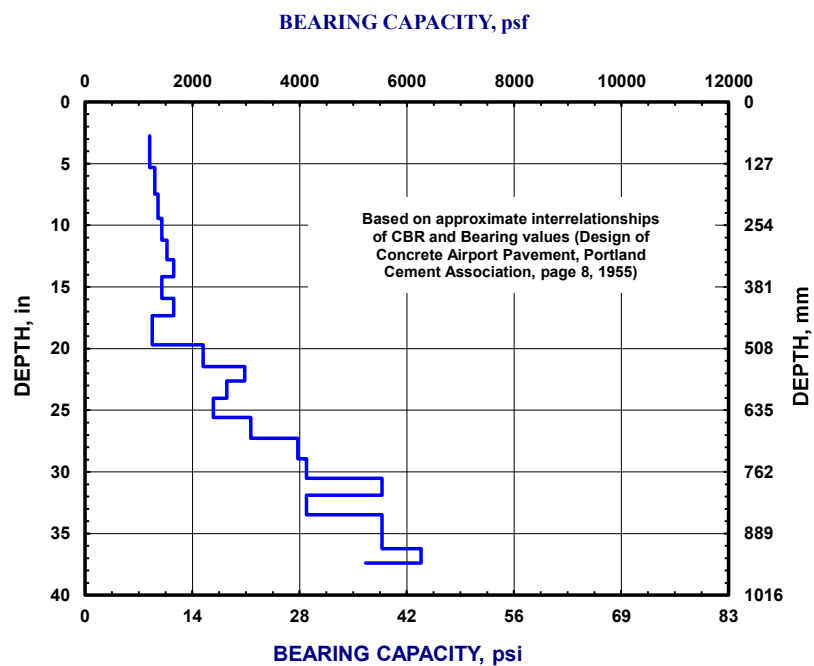
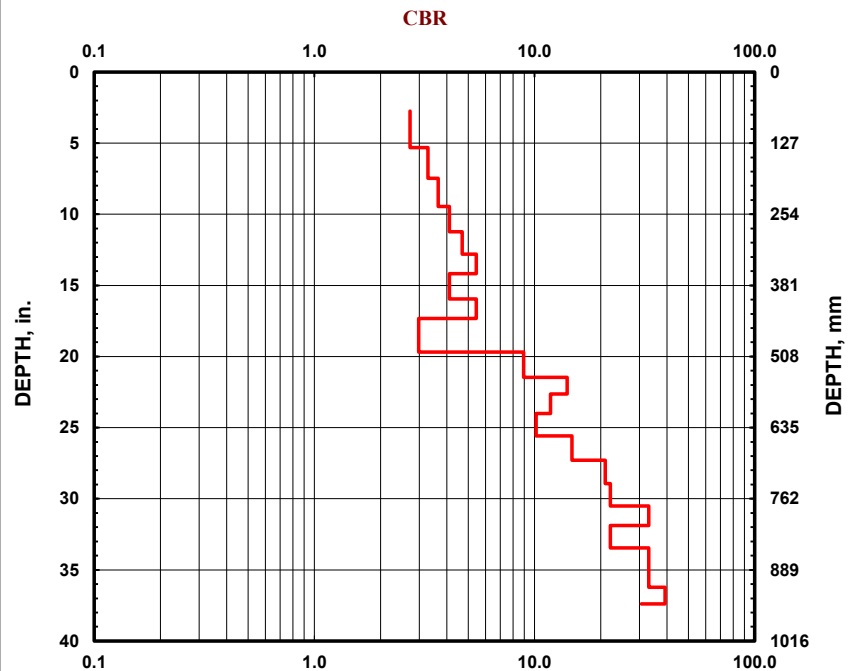
☐ Both hammers used

○ CH

- CL

○ All c

☐ All other soils

[illegible]

DCP TEST DATA

Project: TU220175 COT Maintenance Zone 5027

Date: 23-Aug-22

Location: HB-06

Soil Type(s):

— Hammer —

○ 10,1 ms.

● 17.6 lbs.

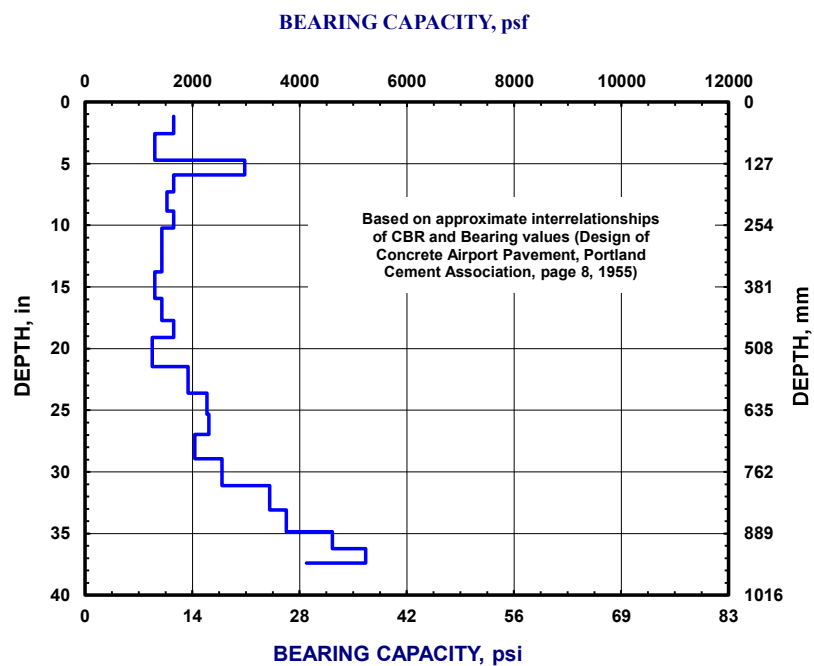
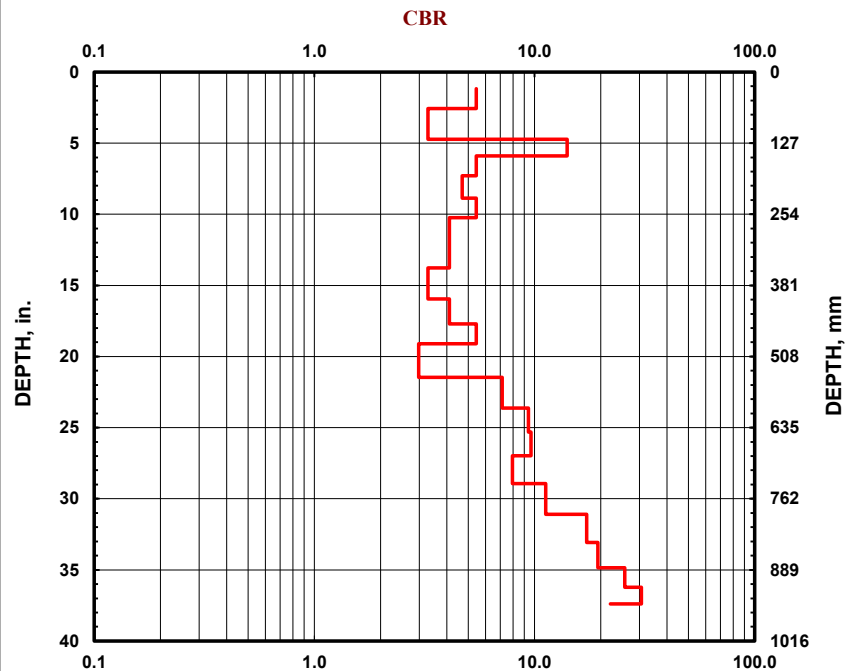
☐ Both hammers used

- Son Type
 0 CH

○ CH

● CL

☐ All other soils

[illegible]

PHOTOGRAPHS OF PAVEMENT SURFACE CONDITIONS

BUILDING & EARTH

Geotechnical, Environmental, and Materials Engineers



PROJECT NAME

COT MAINTENANCE ZONE 5027 – TULSA, OK

PROJECT NO.

TU220175

SCALE

NTS

SITE RECONNAISSANCE PHOTO LEGEND



Photo 1



Photo 2



Photo 3



Photo 4



Photo 5



Photo 6



Photo 7



Photo 8



Photo 9



Photo 10



Photo 11



Photo 12



Photo 13



Photo 14



Photo 15



Photo 16

LABORATORY TEST PROCEDURES

A brief description of the laboratory tests performed is provided in the following sections.

DESCRIPTION OF SOILS (VISUAL-MANUAL PROCEDURE) (ASTM D2488)

The soil samples were visually examined by our engineer and soil descriptions were provided. Representative samples were then selected and tested in accordance with the aforementioned laboratory-testing program to determine soil classifications and engineering properties. This data was used to correlate our visual descriptions with the Unified Soil Classification System (USCS).

NATURAL MOISTURE CONTENT (ASTM D2216)

Natural moisture contents (M%) were determined on selected samples. The natural moisture content is the ratio, expressed as a percentage, of the weight of water in a given amount of soil to the weight of solid particles.

ATTERBERG LIMITS (ASTM D4318)

The Atterberg Limits test was performed to evaluate the soil's plasticity characteristics. The soil Plasticity Index (PI) is representative of this characteristic and is bracketed by the Liquid Limit (LL) and the Plastic Limit (PL). The Liquid Limit is the moisture content at which the soil will flow as a heavy viscous fluid. The Plastic Limit is the moisture content at which the soil is between "plastic" and the semi-solid stage. The Plasticity Index ($PI = LL - PL$) is a frequently used indicator for a soil's potential for volume change. Typically, a soil's potential for volume change increases with higher plasticity indices.

MATERIAL FINER THAN NO. 200 SIEVE BY WASHING (ASTM D1140)

Grain-size tests were performed to determine the partial soil particle size distribution. The amount of material finer than the openings on the No. 200 sieve (0.075 mm) was determined by washing soil over the No. 200 sieve. The results of wash #200 tests are presented on the boring logs included in this report and in the table of laboratory test results.

LABORATORY TEST RESULTS

The results of the laboratory testing are presented in the following tables.

BORING NO.	DEPTH	MOISTURE CONTENT (%)	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	% PASSING #200 SIEVE	CLASSIFICATION
HB-01	0.9 - 1.4	23.8	41	16	25	88	CL
HB-01	2.0 - 2.5	20.0					
HB-01	3.0 - 3.5	18.6					
HB-01	4.0 - 4.5	17.7					
HB-02	0.9 - 1.4	21.3					
HB-02	2.0 - 2.5	24.9	55	19	36		
HB-02	3.0 - 3.5	25.1					
HB-02	4.0 - 4.5	22.8					
HB-03	0.9 - 1.4	20.7					
HB-03	2.0 - 2.5	21.4					
HB-03	3.0 - 3.5	22.3	42	17	25		
HB-03	4.0 - 4.5	23.9					
HB-04	0.6 - 1.1	19.0	29	16	13		
HB-04	1.0 - 1.5	24.5					
HB-04	2.0 - 2.5	25.5					
HB-04	3.0 - 3.5	23.8					
HB-04	4.0 - 4.5	24.0					
HB-05	0.8 - 1.3	22.9					
HB-05	2.0 - 2.5	23.6	42	16	26	89	CL
HB-05	3.0 - 3.5	23.8					
HB-05	4.0 - 4.5	21.5					
HB-06	0.8 - 1.3	23.4	35	15	20		
HB-06	2.0 - 2.5	19.2					
HB-06	2.5 - 3.0	24.7					
HB-06	3.5 - 4.0	22.0					

TABLE L-1: General Soil Classification Test Results

Soils with a Liquid Limit (LL) greater than 50 and Plasticity Index (PI) greater than 25 usually exhibit significant volume change with varying moisture content and are considered to be highly plastic

⁽¹⁾ Indicates visual classification. WR indicates weathered rock.

Important Information about This Geotechnical-Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

While you cannot eliminate all such risks, you can manage them. The following information is provided to help.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical-engineering study conducted for a civil engineer may not fulfill the needs of a constructor — a construction contractor — or even another civil engineer. Because each geotechnical-engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client. No one except you should rely on this geotechnical-engineering report without first conferring with the geotechnical engineer who prepared it. *And no one — not even you — should apply this report for any purpose or project except the one originally contemplated.*

Read the Full Report

Serious problems have occurred because those relying on a geotechnical-engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

Geotechnical Engineers Base Each Report on a Unique Set of Project-Specific Factors

Geotechnical engineers consider many unique, project-specific factors when establishing the scope of a study. Typical factors include: the client's goals, objectives, and risk-management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical-engineering report that was:

- not prepared for you;
- not prepared for your project;
- not prepared for the specific site explored; or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical-engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light-industrial plant to a refrigerated warehouse;
- the elevation, configuration, location, orientation, or weight of the proposed structure;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes—even minor ones—and request an

assessment of their impact. *Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

Subsurface Conditions Can Change

A geotechnical-engineering report is based on conditions that existed at the time the geotechnical engineer performed the study. *Do not rely on a geotechnical-engineering report whose adequacy may have been affected by: the passage of time; man-made events, such as construction on or adjacent to the site; or natural events, such as floods, droughts, earthquakes, or groundwater fluctuations. Contact the geotechnical engineer before applying this report to determine if it is still reliable.* A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ — sometimes significantly — from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide geotechnical-construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report's Recommendations Are Not Final

Do not overrely on the confirmation-dependent recommendations included in your report. *Confirmation-dependent recommendations are not final*, because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations *only* by observing actual subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's confirmation-dependent recommendations if that engineer does not perform the geotechnical-construction observation required to confirm the recommendations' applicability.*

A Geotechnical-Engineering Report Is Subject to Misinterpretation

Other design-team members' misinterpretation of geotechnical-engineering reports has resulted in costly

problems. Confront that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Constructors can also misinterpret a geotechnical-engineering report. Confront that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing geotechnical construction observation.

Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical-engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognize that separating logs from the report can elevate risk.*

Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make constructors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give constructors the complete geotechnical-engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise constructors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure constructors have sufficient time to perform additional study.* Only then might you be in a position to give constructors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

Read Responsibility Provisions Closely

Some clients, design professionals, and constructors fail to recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled "limitations," many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help

others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Environmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform an *environmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical-engineering report does not usually relate any environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own environmental information, ask your geotechnical consultant for risk-management guidance. *Do not rely on an environmental report prepared for someone else.*

Obtain Professional Assistance To Deal with Mold

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the *express purpose* of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold-prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, many mold-prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical-engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; *none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.*

Rely, on Your GBC-Member Geotechnical Engineer for Additional Assistance

Membership in the Geotechnical Business Council of the Geoprofessional Business Association exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project. Confer with you GBC-Member geotechnical engineer for more information.



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